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I, Eur Ing James Francis Bradley BSc CEng MIEE MIL, translator to Engineering Translations, of "Hollyhocks", Cherry Tree Road, Farnham Royal, Buckinghamshire, England, hereby declare that I am conversant with the German and English languages and am a competent translator thereof. I declare further that to the best of my knowledge and belief the following is a true and correct translation of the accompanying International Patent Application No. PCT/IB00/00722 in the German language.

Signed this 18th day of December 2000

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For and on behalf of Engineering Translations

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~~Heating-System Components~~ 09/743537

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The present invention relates in general to a heating and air conditioning installation, and in particular to a heating and air conditioning installation for a vehicle.

A conventional heating and air conditioning installation for a vehicle is usually formed by an engine-side coolant circuit and a refrigerant circuit. For a clearer understanding of the invention described below, the term "first fluid circuit" should be understood as meaning the engine-side coolant circuit. In normal heating and air conditioning installations, as well as in the case of the present invention, various heat exchangers, condensers and evaporators are used. In the description of the invention below and in the appended claims, the term "heat exchanger" should be understood as meaning heat exchangers, evaporators and condensers involved in the air conditioning; in other words, the term "heat exchanger" is intended to cover only the components directly involved in the air conditioning, and not units which are used to deliver or take heat to or from the surrounding air, such as a heat sink which is used to dissipate the waste engine heat, for example.

Taking into account the definitions above, a normal heating and air conditioning installation is made up of a first fluid circuit comprising a first heat exchanger, and a second fluid circuit comprising a second heat exchanger, the heat exchanger of the first fluid circuit usually being used for heating purposes, whereas the heat exchanger of the second fluid circuit, usually designed as an evaporator, is used for cooling.

In order to improve the heating performance of such heating and air conditioning installations, a va-

riety of attempts have been made to raise the heating performance of the first heat exchanger by providing additional equipment, such as e.g. PTC heating registers, fuel cells, etc. These approaches are, however, relatively complex to implement and entail relatively high overall fitting costs for the heating and air conditioning installation.

US 5,291,941 has therefore proposed a heating and air conditioning installation in which the second fluid circuit can be used for both cooling and heating purposes. As a further development, this document also describes a heating and air conditioning installation which comprises three fluid circuits, namely a first fluid circuit which provides heat from the internal combustion engine for heating purposes via a first heat exchanger, a second fluid circuit which is configured as a conventional refrigerant circuit for cooling, and a third fluid circuit, which is designed as a thermodynamic heating circuit. This preferred embodiment corresponds to the precharacterizing clause of Claim 1.

Although this known heating and air conditioning installation enables optimization of the second and third heat exchangers for cooling and heating purposes, respectively, this embodiment has nevertheless been found to be inadequate with respect to currently required response times and control facilities.

The object of the present invention is therefore to refine an air conditioning installation of the generic type, in particular for a vehicle having a first fluid circuit comprising a first heat exchanger, a second fluid circuit comprising a second heat exchanger, and having a third fluid circuit comprising a third heat exchanger, in such a way as to provide shorter response times and an improved control facility.

According to the invention, this object is achieved in that the second and/or third heat exchanger is connected downstream of the first heat exchanger in terms of air-flow technology. In contrast to the prior art, it is hence possible to connect at least one heat exchanger downstream of the heat exchanger of the engine-side coolant circuit in terms of air-flow technology, so that e.g. when the engine is cold in the phase of starting the vehicle, the heating power of the assigned thermodynamic heating circuit is made available virtually immediately, since no part of the heat generated when heating up the first heat exchanger is lost. In heating operation, in particular, the downstream connection of a further heat exchanger of a thermodynamic heating circuit offers an optimized control facility, since the final adjustment of the air to be delivered into the passenger compartment can be carried out by means of this heat exchanger.

In an advantageous refinement of the heating and air conditioning installation, three heat exchangers are arranged in series in terms of air-flow technology, so that the first heat exchanger of the engine-side fluid circuit is arranged between the second and third heat exchangers. For example, air blown by a fan could thus first pass through an evaporator intended for cooling purposes, then through the heat exchanger of the coolant circuit and then through the heat exchanger of a thermodynamic fluid circuit designed for heating purposes. The fact that the heat exchanger used for cooling purposes is connected upstream of the heat exchangers used for heating purposes means that the moisture formed by the heat exchanger used for cooling purposes no longer constitutes a problem, even in heating mode. This moisture formation was particularly problematic in the prior art, and frequently caused the win-

dows to fog up in the motor vehicle. However, since the air passing through the heat exchanger used for cooling purposes is at a relatively low temperature, this air takes up only a little moisture. The result of this is that, after the heating which follows by means of the first heat exchanger of the engine-side fluid circuit and the subsequent final heating by means of the down-stream heat exchanger of a thermodynamic fluid circuit, the total humidity of the emerging air is negligible, which means that the windows no longer fog up. By providing an upstream heat exchanger used for cooling purposes and a downstream heat exchanger used for heating purposes, with respect to the first heat exchanger of the engine-side fluid circuit, it is furthermore possible to optimize the configurations of the second and third heat exchangers. This makes it possible to avoid the noise emissions which result in the prior art when only one heat exchanger in addition to the engine-side heat exchanger is used for both cooling and heating purposes.

Advantageously, the downstream heat exchanger or heat exchangers are formed as a structural unit with the first heat exchanger, the respective heat exchangers being in particular thermally isolated from one another. This arrangement makes it possible to combine the heat exchangers used for heating purposes in a compact way while maintaining thermal isolation.

In order to reduce the number of components necessary, for instance fluid delivery means and the like, it is preferable if the second and the third fluid circuits are coupled to one another, one fluid circuit, in particular, representing a bypass with respect to the other fluid circuit. In this way, the two thermodynamic fluid circuits can be combined into an overall circuit which can be used selectively, by means of suitable

control elements, for heating and/or for cooling. An advantage of the bypass-type configuration is that no reversal is any longer necessary when changing between cooling and heating operations.

Advantageously, fluid-flow and/or state control means are provided in the transition region between the second and third fluid circuits. These means may be used, on the one hand, to switch the respective mode between heating and cooling and, on the other, for controlling the power level of the corresponding operating mode. The fluid-flow control means and the fluid-state control means may be designed as combined equipment, for instance in the form of a three-way valve, one outlet being designed as a throttle, or alternatively as separate equipment, for instance control valves in conjunction with separate throttle points, e.g. in the form of a throttle valve or a cross-sectional constriction in the delivery line.

In a particularly advantageous embodiment, at least one fluid-flow and/or state control means is arranged in such a way that it can affect both the fluid flow and the fluid state, e.g. designed as a throttle, it being particularly advantageous if the throttle function is achieved by forming a two- or multi-stage throttle. In the multi-stage version a large resistance might for instance be selected when the thermodynamic fluid circuit is being heated, and switched over to a state with low resistance when the heat required to achieve the desired heating performance is sufficient.

In order to improve yet further the control facility when switching between cooling and heating modes, it may be advantageous to provide separate control means for the individual fluid circuits, for instance in the form of simple shut-off valves or via a

non-return valve, which may optionally be provided with a temperature controller.

In order to improve further the response of the heating and air conditioning installation according to the invention, an air-flow control means may be connected upstream of at least one heat exchanger, in particular for diverting or delivering air with respect to the heat exchanger in question. In other words, in this configuration there are means for providing an air bypass for one or more heat exchangers. In cooling mode, it might for instance be advantageous to deliver the air exclusively through the evaporator, i.e. the heat exchanger used for cooling purposes, without it flowing through the heat exchangers used for heating purposes, which might possibly still have a certain amount of residual heat stored. When subsequently switching over from cooling mode to heating mode, the flow through the heat exchanger used for cooling purposes could be stopped, so that the air flows exclusively through the heat exchanger used for heating purposes. Accordingly, the available heating power is not compromised by the residual cold in the heat exchangers used for cooling purposes. The response is hence improved significantly, and in particular the heat exchanger used for heating purposes may be able to retain residual heat since it has not been cooled in the cooling mode.

Lastly, it is preferable if a phase change of the fluid takes place in at least one heat exchanger. In other words, at least one heat exchanger should be designed as an evaporator or a condenser, so that the fluid circuit of this heat exchanger can be regarded as a thermodynamic heating or cooling circuit.

Other advantages and features of the present invention will be found in the following detailed description of a few currently preferred, purely illus-

trative embodiments, which is given with reference to the appended drawings, in which:

Fig. 1 shows a first preferred embodiment of the heating and air conditioning installation according to the invention, in which three discrete fluid circuits are provided.

Fig. 2 shows a second preferred embodiment of the heating and air conditioning installation according to the invention, two fluid circuits being combined or coupled with one another.

Fig. 3 shows a further preferred embodiment, similar to the embodiment shown in Fig. 2, the heat exchangers involved in the air conditioning being arranged in series.

Fig. 4 shows two heat exchangers which are combined with one another as a structural unit, and which form part of a preferred embodiment of the invention.

Fig. 5 shows a detailed view of heat exchangers arranged in series, with assigned air-flow control means.

Figs. 6a to e show various possible fluid-flow and/or state control means for coupled fluid circuits.

Fig. 7 diagrammatically shows the thermodynamic fluid circuits of a particularly preferred embodiment of the heating and air conditioning installation according to the invention.

Fig. 1 diagrammatically represents a first preferred embodiment of the heating and air conditioning installation according to the invention. The heating and air conditioning installation comprises a first fluid circuit 10 comprising a first heat exchanger 12. This first fluid circuit 10 represents the engine-side cooling circuit which, for example, may be used to cool an internal combustion engine 1. The components of the first fluid circuit 10 are conventional and it com-

prises, besides the heat exchanger 12 used for heating purposes, fluid delivery means 5, a bypass line 2 controlled by means of a thermostat 3, and a heat sink 4 which interacts with the surrounding air. A fan or blower 14 is provided for application to the heat exchanger 12 in terms of air-flow technology.

In some driving situations, in particular after a cold start, the heating power provided by the heat exchanger 12 is not sufficient to bring the vehicle interior to a desired temperature. In the embodiment shown, a further heat exchanger 32, which is identified as the third heat exchanger 32 in the description below, is therefore connected downstream of the heat exchanger 12 in terms of air-flow technology. The third heat exchanger 32 is supplied via a thermodynamic heating circuit 30 which, in the conventional way, comprises fluid-application means 33 and fluid-expansion means 36. The downstream connection of the third heat exchanger 32 accordingly makes it possible to optimize the heating performance which is set, in terms of control technology; for example, after a cold start it is possible to achieve improved response if the third heat exchanger 32 can supply heat even when the heat exchanger 12 of the first fluid circuit is still cold.

In order to make it possible, when required, to obtain air conditioning or possibly also dehumidification, a heat exchanger 22 used for cooling purposes is arranged upstream of the first heat exchanger 12 in terms of air-flow technology. This heat exchanger 22 used for cooling purposes will be defined below as the second heat exchanger 22, and is usually designed in the conventional way as an evaporator. The second heat exchanger 22 is supplied through a second thermodynamic fluid circuit which, in the usual way in these instances, comprises fluid-delivery and/or application

means 25 and fluid-expansion and/or throttle means 26. The second fluid circuit 20 may optionally also comprise a heat sink 24, which is used to supply the surrounding air with heat which is not required for controlling the temperature of the passenger compartment in pure cooling operation. This heat sink 24 is designed in the conventional way as a condenser.

The series arrangement of heat exchangers, in the sequence of second heat exchanger 22, first heat exchanger 12 and third heat exchanger 32, makes it possible to achieve optimum control of the temperature of the air to be fed into the passenger compartment. In the embodiment represented here, the temperature of the air is controlled exclusively by means of fluid-technology control of the three fluid circuits, although additional air-flow control means may also be provided, as discussed further on in the present description.

It can be stated that the downstream connection of the third heat exchanger allows an optimized configuration of the heat exchanger for the fluid for heating purposes, with the additional possibility of re-warming and hence optimized temperature control of the air entering the passenger compartment. In this way, it is possible to eliminate noise emission problems which result in the prior art if only one heat exchanger is used for cooling and heating purposes. The upstream arrangement of the second heat exchanger with respect to the first heat exchanger 12 makes it possible to cool the air entering the passenger compartment in a suitable way, switching from cooling mode to heating mode being readily possible without the moisture present in the second heat exchanger 22 having the potential to constitute a problem. The upstream connection of the second heat exchanger 22 in terms of air-

In Figure 1

flow technology does provide an optimized solution in terms of compactness, but it is also possible to provide the heat exchanger 22 used for cooling in a separate channel or in parallel with the first heat exchanger 12. Such an embodiment is represented in Fig. 2.

In the embodiment represented in Fig. 2, the second fluid circuit 20 and the third fluid circuit 30 are represented as a coupled fluid circuit, so that only one fluid-delivery and/or application means 25 is needed for the two circuits. As represented, the third fluid circuit with the heat exchanger 32 used for subsequent temperature control forms a bypass with respect to the second fluid circuit 20. In order to switch between heating and cooling modes, for example, two three-way valves 35 are simply operated for application to the second fluid circuit 20 or the third fluid circuit 30. It should be mentioned that, if a certain degree of dehumidification is desired, mixed operation may also be carried out. In other words, the control valves 35 are set in such a way that both the heat exchanger 32 and the heat exchanger 22 are supplied with fluid, on one hand in order to provide cooling in order to dry the air and, on the other, in order to provide heating which is used to raise the air entering the passenger compartment to a desired temperature immediately before it emerges.

Fig. 3 represents a third preferred embodiment, the structure of which corresponds essentially to the embodiment represented in Fig. 2. As in the embodiment represented in Fig. 2, the two thermodynamic fluid circuits 20 and 30 are coupled to one another, although in this embodiment the heat exchangers 22, 12, 32 are arranged in series, specifically in a similar way to the embodiment represented in Fig. 1. The advantages of the

series.

embodiments shown in Figs. 1 and 2 can accordingly be achieved in combination.

Fig. 4 represents the first heat exchanger 12 and the third heat exchanger 32, i.e. the two heat exchangers used for heating purposes, as a combination unit, the design of the unit being such that thermal decoupling exists between the two heat exchangers. This arrangement of the heat exchangers in the form of a tandem radiator allows compact fitting. As is represented in Fig. 4, further thermal decoupling can take place if the feed lines for coolant or refrigerant are offset relative to one another.

The form of the tandem radiator may, however, also be configured in another suitable fashion, for example as a hollow body which, in segmented fashion, in sections or as mentioned above in thermally separated and parallel-running fashion, is applied in co-current or counter-current flow by the corresponding fluid circuits.

Fig. 5 represents the series arrangement of the heat exchangers 22, 12, 32 in conjunction with air-flow control means, which make it possible to feed air through the respective heat exchangers or divert air past them. This arrangement makes it possible to reinforce or replace the fluid-side control; in any case the response is improved since residual heat and residual cold can respectively remain in the relevant heat exchangers when not being used. In terms of flow technology, one channel 40 contains, downstream of the fan 14, the heat exchanger 22 used for cooling purposes and the heat exchangers 12 and 32 used for heating purposes, which are provided as a combination unit. Two control flaps 42 and 44 which, as represented, may enable or prevent application to the heat exchanger 22, are arranged upstream of the heat exchanger 22 used for

cooling purposes. Correspondingly, the air is fed either through the heat exchanger 22 or past the latter in bypass fashion. Correspondingly, an air-flow control means with two flaps 46 and 48 is arranged upstream of the combination unit consisting of the two heat exchangers 12, 32 used for heating purposes, so that the air can be caused to pass through these heat exchangers or be fed past them. Since the application to the individual heat exchangers can be chosen selectively according to the operating mode, the responsiveness of the overall circuit may be significantly improved, especially since, during cooling, the residual heat contained in the heat exchangers 12, 32 used for heating purposes does not compromise the cooling power, whereas during heating, the heat exchanger 22 used for cooling need not be heated up initially. When switching between cooling and heating modes, the remaining residual heat or residual cold can hence advantageously be used immediately.

Figs. 6a to e represent various possible ways in which the thermodynamic second fluid circuit 20 used for cooling purposes and the third fluid circuit 30 used for heating purposes, which [sic] may be coupled to one another, various possible ways of expanding the fluid in the third thermodynamic heating circuit 30 being in particular represented.

Sub B1 In Fig. 6a, a three-way valve 35, which can selectively apply to one of the fluid circuits 20, 30 or both fluid circuits 20, 30 in respective proportions, is connected downstream of the fluid-delivery means, or compressor, 25 in terms of fluid-flow technology. For the third fluid circuit 30 used for heating purposes, a throttle point 36 in the form of an expansion valve is arranged downstream of the three-way valve 35. The third heat exchanger 32, which is used as an after-

heater the for the engine-side fluid-circuit heat exchanger, is located further downstream. A non-return valve is furthermore provided at the interface with the second fluid circuit 20 used for cooling purposes.

In the embodiment shown in Fig. 6b, the throttle point 36 and the three-way valve 35 are combined to form one unit 34, in which the outlet directed toward the third fluid circuit 30 is used as a throttle.

In the embodiments represented in Figs. 6c and 6d, the throttle function respectively is achieved by two valves 36 and by hoses or lines with reduced diameters 37, it being possible for corresponding throttling of the fluid used for heating purposes to take place on both sides of the heat exchanger 32.

In the embodiment shown in Fig. 6e, two three-way valves, the respective inlet or outlet of which are designed as throttle points toward the third fluid circuit 30, are provided one on each side of the fluid-delivery or application means 25.

Finally, Fig. 7 shows another possible combination between the second and third thermodynamic fluid circuits 20, 30, in a representation corresponding essentially to that in Fig. 2. In order to increase the control facility, in the embodiment represented here a pair of control valves 35 for the respective fluid circuits is connected downstream of the compressor 25. In the embodiment represented here, a two-stage throttle, which has slight resistance when there is enough heat present in the thermodynamic heating circuit 30, is connected downstream of the heat exchanger 32 used for heating purposes. In the heating phase, for example after a cold start of the vehicle, the resistance can be adjusted to measure, so that rapid heating can be carried out by means of the throttle 38 with high resistance. Consequently, the heat exchanger 32 can provide

heat for the passenger-compartment heating system just a short time after starting, so that a satisfactory heating function can be fulfilled almost immediately after the start.

In conclusion, it may be stated that the solution according to the invention provides a heating and air conditioning installation which enables rapid response to a very wide variety of settings, substantially independently of external conditions and states in the system. In contrast to other approaches, such as when PTC heating registers or fuel cells are used, only known thermodynamic components are required in the proposed solution; it is advantageously possible to reduce the number of parts required further if the thermodynamic fluid circuits are coupled or connected to one another. In this way, a facility for optimized control of the overall system is provided, without excessive space being required.

Although the present invention has been described above completely and with reference to the appended drawings, the person skilled in the art should realize that a very wide variety of changes and modifications are possible in the scope of the claims. In particular, it should be pointed out that the individual features of one embodiment can be combined at will with other features of other embodiments.